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Dynamic voltage restorer quality improvement analysis using particle swarm optimization and artificial neural networks for voltage sag mitigation

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ABSTRACT

Power quality is one of the problems in power systems, caused by increased nonlinear loads and short circuit faults. Short circuits often occur in power systems and generally cause voltage sags that can damage sensitive loads. Dynamic voltage restorer (DVR) is an efficient and flexible solution for overcoming voltage sag problems. The control system on the DVR plays an important role in improving the quality of voltage injection applied to the network. DVR control systems based on particle swarm optimization (PSO) and artificial neural networks (ANN) were proposed in this study to assess better controllers applied to DVRs. In this study, a simulation of voltage sag due to a 3-phase short-circuit fault was carried out based on a load of 70% of the total load and a fault location point of 75% of the feeder's length. The simulation was carried out on the SB 02 Sibolga feeder. Modeling and simulation results are carried out with MATLAB-Simulink. The simulation results show that DVR-PSO and DVR-ANN successfully recover voltage sag by supplying voltage at each phase. Based on the results of the analysis shows that DVR-ANN outperforms DVR-PSO in quality and voltage injection into the network.

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1. INTRODUCTION

Power quality is one of the main issues in the electric power system. It is because, along with the increasing need for loads on the consumer side, electricity producers are required to have continuity and reliable power availability. On the other hand, electrical loads are intolerant to voltage changes. In many cases of electrical power quality, voltage quality is the most widely handled because 80%-90% of consumers are affected by voltage disturbances and resulting losses [1], one of which is voltage sags. Voltage sags, a major disturbance in the power system, greatly affect sensitive loads that are intolerant to voltage changes. This voltage sag occurs when the voltage changes with a range of 10%-90% at the rms value of the voltage for a duration of 0.5 cycles (0.01 seconds) to 1 minute. This is due to several factors, namely the use of nonlinear loads, supply to large loads, variations in loading, short circuit faults, and poor system design [2]–[5]. Various techniques, including power electronic devices, solve electrical power quality problems. This device concentrates on the reliability and quality of the power flow of the system applied to the distribution system [6]–[8]. Various types of power electronics devices are active power filters (APF) [9], Battery energy storage systems (BESS) [10], distribution static synchronous compensators (DSTATCOM) [11], dynamic voltage restorer (DVR) [12]–[14]. DVR, one of the power electronics devices, is effective in distribution systems because it requires lower power than other devices, lower maintenance costs, good efficiency, simpler control, and easy implementation [15]. DVRs are connected in series on the distribution network, used to regulate voltage on the network if needed, and used to protect against short-term voltage disturbances between supply and sensitive load [16]. In research [17], the effect of DVR installation on voltage sag on various types of short circuit faults was analyzed. Based on simulations, the largest disturbance was caused by a 3-phase to ground short-circuit fault. The amount of load supplied and the distance of the fault location also affects how much the voltage drops. Moreover, to improve the quality of the DVR is to improve the quality of its control system. The quality of the control system is influenced by the type of control strategy used [18]. This component plays an important role in detecting faults from the voltage supplied and comparing it with the reference voltage. Proportional integral (PI) controller is a controller commonly used in DVRs, but the response is not good to nonlinear loads, as well as long time delays and settling times [19].

Jeyaraj *et al.* [16] introduced particle swarm optimization (PSO) to improve the quality of DVRs by setting on the PI controller. The study used a simple distribution system and was tested on different short-circuit faults. The results showed that PSO successfully improved the response and quality of voltage injection on the DVR. In a related study, Salman *et al.* [18] proposed the adaptive neuro-fuzzy interference system (ANFIS) method to improve the response of the DVR by adjusting the response through the PI-PSO controller. PI-PSO successfully regulates the response for the proposed method, and the PI-PSO response setting is better than the PI controller in the study results. In contrast, comparing and improving the types of reliable control strategies on DVRs is one method of finding the most efficient controller to use [19]. Research by Arpitha *et al.* [20] used a similar method, comparing types of strategy control, namely artificial neural network (ANN) and hysteresis voltage control. This study used photovoltaic as a direct current (DC) source on the DVR, then simulated the sag and swell due to a 3-phase short-circuit fault. The results show that the ANN controller is a more reliable method used in DVRs, with advantages including the ability of the network to learn from experience, self-organize, parallel processing, and the twofold function of the neuron [21]. Research by Ibrahim [22] uses ANN as a control system on DVRs to compensate for voltage sag. ANN input and output data are trained using different types of training algorithms. The most suitable algorithm used according to the simulation results is Lavenberg-Marquardt, and the ANN controller is able to recover voltage with a total harmonic distortion (THD) of 3.50%.

Based on the problem described above. PSO and ANN were introduced as a solution to this problem. PSO is a reliable metaheuristic method that can optimize the controller's performance with few parameters, but the results are optimal. Convergence and optimum values are obtained faster than other methods and do not depend on parameters [20]–[22]. This study proposed to test DVR based on PSO and ANN to find a more suitable controller. Modeling and simulation were carried out using MATLAB Simulink. The simulation was performed based on a 3-phase short-circuit fault based on 70% load and 75% fault location. Simulations were conducted on the distribution network at the SB02 feeder of the Sibolga substation, and the performance of the DVR was analyzed.

2. PROPOSED METHOD

2.1. Dynamic voltage restorer

Dynamic voltage restorers (DVRs) are installed in the distribution system to protect sensitive loads from voltage sag. DVR is considered a variable that can be controlled and linked in series between point of common coupling (PCC) and load [13], [23]. DVR injects the voltage the inverter generates when a disturbance occurs using a 3-phase transformer in series. DVR consists of several components, a battery as an energy source, DC to AC inverter, a filter to reduce harmonics, an injection transformer, and a control circuit. When a fault occurs, the control unit on the DVR detects a measured voltage change in the load. Then the control unit will generate pulses on the voltage source inverter (VSI), and VSI responds by generating AC voltage. The resulting AC voltage contains harmonics, so the low-pass filter works to get a better waveform. Then the voltage is stepped up to nominal voltage and then injected through an injection transformer [13], [24].

DVR works with three operating modes, namely standby mode, when the system is in a normal state [18], [25]. When voltage sag occurs, the DVR goes into injection mode, where the DVR supplies the required voltage, phase, and frequency. When a fault occurs, a large current flow into the network, and the DVR goes into protection mode by activating a bypass switch to protect the DVR circuit from disturbances. Figure 1 shows the components contained in a DVR.

Voltage compensation by the DVR is carried out with the required magnitude and phase angle. The power injected by the DVR is in the form of active and reactive power. The amount of power injected can be